(2)

SURVEY OF HAZARDOUS CHEMICAL PROTECTIVE SUIT MATERIALS FOR SHIPBOARD USE

NAVY CLOTHING AND TEXTILE RESEARCH FACILITY
NATICK, MASSACHUSETTS

Approved for public release;
distribution unlimited.

TECHNICAL REPORT NO. NCTRF 193

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	1 March 1993	Final Nov 91 - Mar 93

4. TITLE AND SUBTITLE
SURVEY OF HAZARDOUS CHEMICAL PROTECTIVE SUIT MATERIALS FOR SHIPBOARD USE

5. FUNDING NUMBERS
62-1-90

6. AUTHOR(S)
Heath, Cleveland A.

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Navy Clothing and Textile Research Facility
P.O. Box 59
Natick, MA 01760-0001

8. PERFORMING ORGANIZATION REPORT NUMBER
NCTRF Technical Report 193

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for Public Release: Distribution Unlimited

12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)

The Navy Clothing and Textile Research Facility has conducted a survey of selected materials for potential use in a hazardous chemical protective ensemble, and subsequently subjected these materials to a laboratory evaluation for durability and the results are presented in this report. An overview of the current Naval posture on hazardous chemical minimization and control is also synopsized. Protective clothing levels, governing standards and ensemble types are also discussed. The report concludes that there is a need to develop a hazardous chemical protective ensemble that will provide protection for fire-fighters in the event of a hazardous chemical fire.

14. SUBJECT TERMS

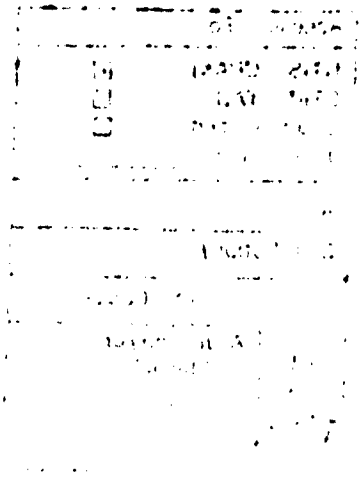
15. NUMBER OF PAGES
21

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	

TABLE OF CONTENTS

LIST OF TABLES



SURVEY OF HAZARDOUS CHEMICAL PROTECTIVE SUIT MATERIALS FOR SHIPBOARD USE

INTRODUCTION

In support of Navy Clothing and Textile Research Facility (NCTRF) project HAZARDOUS CHEMICAL PROTECTIVE MATERIALS FOR USE IN FIREFIGHTING APPLICATIONS 62-1-90, a comprehensive survey of all commercially available, and experimental hazardous chemical protective suit materials has been conducted. The purpose of this survey was to identify potential candidate materials for use in the development of a hazardous chemical protective ensemble that would be used in the event of a hazardous chemical spill aboard ship. Materials that were purported to meet the proper level of chemical protection for this application were obtained and subjected to laboratory evaluation. This report is an adjunct of NCTRF Technical Report #186 "Survey of Hazardous Chemical Protective Suit Materials".

BACKGROUND

The United States Navy utilizes hundreds of hazardous materials for routine maintenance operations on land and onboard ship. Although these materials are currently being reviewed, catagorized, and their numbers reduced, the presence of hazardous material still presents potential problems.

The Naval Safety Center in Norfolk, VA., in accordance with the Hazardous Material Afloat Program, has produced a master list of hazardous materials known as the Ships Hazardous Material List (SHML), which identifies authorized substances for shipboard use. The intent of this list is to provide a document to each ship which will identify all of the hazardous materials, state the unit of issue for each, and to preclude stocking of dangerous chemicals for which the ship has no need.

In support of the SHML, a listing of all Material Safety Data Sheets (MSDS) for all shipboard chemicals has been compiled in a floppy disk format. This listing is known as the Automated Hazardous Material Retrieval Tracking System, and is updated quarterly by the Naval Regional Data Automated Center in Norfolk, VA. The listing is available to all ships for the purpose of supporting their Hazardous Materials Program.

Although there are hundreds of hazardous materials stored aboard ship, they are retained in very small quantities, with the majority of the chemicals being used for cleaning or painting-related tasks. Proper handling of these materials is important, and preparation must be made for proper action in the event of a spill. This would include the use of adequate personal protective equipment, containment devices and safety procedures.

The Naval Ship Systems Engineering Station has developed a Hazardous Materials Response Kit that is specifically designed for the cleanup of hazardous chemical spills. Included in the spill kit is a coverall that utilizes a "Saranex"-coated "Tyvek" nonwoven material. This material is inexpensive, and is therefore commonly used for disposable garments. The disadvantage of using a suit of this type is that the material does not provide complete chemical protection. The material does, however, offer good splash protection from many chemicals, but would not be recommended for protection from chemical vapors.

The Naval Safety Center advised NCTRF that the level of protection afforded by the "Saranex"-coated "Tyvek" material is adequate for any chemical spill scenarios that may be encountered onboard ship. The Center also stated that no injuries have been reported to date that are associated with a hazardous chemical spill. Based on this information, it was determined that no need exists for the development of a more sophisticated shipboard hazardous chemical protective garment, and, as a result of the Center's recommendation, our work efforts have since turned toward development of a hazardous chemical protective garment for firefighting applications. This was based on conversations with environmental coordinators, and fire marshalls from various Naval Facilities throughout the United States who unveiled a need for a hazardous chemical protective suit that will be impervious to all chemicals, and will also be fire retardant.

The commercial market offers many types of hazardous chemical protective suits with varying levels of durability, flame retardancy and chemical resistance. All of these ensembles have limitations, but the major deficiency is in the area of flame resistance. The ultimate material, when developed into a garment, will allow firefighters to enter a fire where hazardous chemicals are stored, and the potential for ignition of these chemicals exists. The current approach to combating fires of this type is to stay clear of the area, and to let the fire burn itself out.

PROTECTIVE CLOTHING SURVEY

a. General Information

In support of the investigation into a suitable material for fire entry, a survey of all manufacturers of hazardous chemical protective suits was conducted and discussed in NCTRF Technical Report #186 "Survey of Hazardous Chemical Protective Suit Materials", as well as research into governing standards, levels of protection and available fabric laminates.

Prior to the selection of a material and suit design, the level of performance expected from the end-item must be determined. This is always very difficult to do when faced with protecting against a large variety of chemicals, or when dealing with chemicals of an unknown nature, as opposed to an environment where only a limited number of chemicals are stored or produced. When attempting to determine the proper level of protection in situations where a synergistic effect may result from the mixing of two or more chemicals, it is always advised to be outfitted with a suit that is designed for the next highest level of protection.

The Occupational Safety and Health Administration's Environmental Protection Agency has established categories (Levels A,B,C, and D,) for determining the appropriate level of protection for the anticipated situation. The greatest protection is afforded by Level A, and the least by Level D. The achievement of Level A protection requires a totally encapsulated suit, which is vapor impermeable. This level of protection would be recommended when unknown chemicals are present, when operations will occur in confined spaces, or where chemical vapors may be present. The National Fire Protection Association (NFPA) has developed standards that further define various levels of exposure and protective clothing requirements associated with those levels. The obtaining of certification (NFPA 1991 Vapor-Protective Suits for Hazardous Chemical Emergencies) requires that the Level A ensemble meet or exceed minimum requirements in areas such as chemical permeation (before and after abrasion), tensile strength, flammability, flexural fatigue, and cold temperature performance testing. The NFPA has established similar requirements for other protection levels, but none as stringent as that for meeting NFPA 1991 protection standards.

b. Disposable Garments

Hazardous chemical protective clothing is available in a variety of styles and materials, ranging from the inexpensive disposables, through expensive, reusable suits. The disposable

garments are commonly constructed from materials such as a "Saranex"/"Tyvek" laminate or "Barricade", a heavier, more durable and chemically resistant laminate consisting of a coextruded multiple layer film, laminated to a nonwoven substrate. Disposable garments are available in aprons, bibbs, coveralls, as well as totally encapsulated suits. Due to the lack of chemical vapor protection offered by these disposable suits, they are not acceptable for Level A applications, even when a totally encapsulated suit is worn.

c. Limited Use Garments

The next step up in protective ensembles would be the "limited use" garments, which are defined as those items which may be donned several times, but must be disposed of when the material is damaged or contaminated by hazardous chemicals. These limited use garments may be designed as coveralls, but are primarily intended for totally encapsulated suits, such as those used in Level A protection. Some of these suits may meet all of the required criteria outlined in NFPA 1991 Vapor-Protective Suits for Hazardous Chemical Emergencies, although they would require an aluminized flashcover to pass the abrasion and flame resistance tests. These suits incorporate sophisticated films and elastomers designed to achieve excellent chemical permeation resistance, but may also utilize the "Barricade" material. The "Barricade" or similar laminates may be used if they will provide the chemical resistance that is required for the particular application. Aluminized flash protective covers are an integral part of any suit when addressing hazardous chemical environments where the potential for a flash exists, but they also have limitations. The greatest disadvantage is that these expensive ($500.00 - $1000.00 each) covers cannot be decontaminated if exposed to a chemical challenge and, therefore, must be discarded. The concept of a multipiece flashcover allows for disposal of the piece that has been contaminated, but the question of whether any other piece may have been exposed always exists. The Trelleborg organization, however, is working on a less expensive, disposable, aluminized nonwoven to solve this problem.

d. Reusable Garments

Reusable hazardous chemical protective suits are the next tier of protective clothing. They are the highest priced suits, but are capable of being decontaminated. Consequently, the life expectancy will be extended, thereby reducing the cost per use. These reusable suits are available in elastomeric materials such as butyl, "Viton", polyvinylchloride, and chlorinated

polyethylene. They are also available in a material catagorized as "cast films". Cast films utilize several films, each possessing exceptional resistance to specific chemical groups, joined together to form a multi-functional barrier. Another approach is to bond products with excellent chemical resistance, such as "Teflon", to substrates of "Nomex" or "Kevlar", thereby producing a strong fire retardant and chemically resistant laminate. The major disadvantage of a reusable suit is the decontaminaion aspect, since it is difficult to be certain that the suit has been thoroughly decontaminated. Consequently, a reliable method of determining the efficacy of the decontamination procedure needs to be developed.

ADDITIONAL CONSIDERATIONS

As good as some of these materials may be, there are many other factors to consider when developing a hazardous chemical protective suit. The suit components, auxiliary equipment, and suit construction techniques are all vitally important to the success of a hazardous chemical protective ensemble. Suit components such as the face shield must be examined as closely as the material. In the case of a face shield, it must possess an equal degree of chemical resistance as the body of the suit, plus luminous transmittance and haze resistance qualities. Auxiliary equipment such as communications, respiratory devices, boots, and gloves must be properly integrated with the ensemble for maximum protection and safety.

Suit construction techniques and components are critical elements in the effective production of a quality hazardous chemical protective suit. The design of the garment's closure system, and the selection of the seam technique are of major importance. A variety of seams are available throughout the industry, and, depending upon the final application of the garment, the seam could be as simple as a serged seam, or as complex as a double strapped seam, with a covering of the body material sealed over the seam by heat or radio frequency.

Once a suit has been selected, proper care is required to maintain its benefits. The suit must be stored in a clean, dry environment, and periodic maintenance procedures followed. A visual inspection of the suit is required to examine seams, closures, visor and valve integrity. The suit must be tested for vapor protection by inflating the suit with compressed air, and monitored for pressure drop by means of a pressure gauge. Proper maintenance must be combined with a caring attitude to ensure that the garment will provide the expected protection when called upon, as well as to provide the anticipated life expectancy.

A summary of hazardous chemical protective suit characteristics is contained in TABLE I. The matrix highlights some of the characteristics that should be considered when selecting a garment of this type.

TABLE II consolidates the chemical permeation data, as provided by each manufacturer, for the purpose of comparison. The chemical permeation data are based upon results of testing performed in accordance with American Society for Testing and Materials (ASTM) F739, "Resistance of Protective Clothing Materials to Permeation by Liquids or Gases". TABLES I and II do not include every manufacturer, or every suit that is available from the manufacturers listed, but does represent a large number of suits that are available in today's market. The suits listed represent those that would be of interest for this project. The chemical permeation data are based upon a general list of chemicals that were tested by each of the manufacturers, but prior to the ultimate suit selection, the material would be subjected to specific chemicals, such as Otto Fuel or aqueous film forming foam, that are of particular interest to the Navy.

TABLE I

Summary of Hazardous Chemical Protective Suit General Information

NAME	CHEMICAL PROTECTIVE LEVEL		INTENDED USE		MEETS NFPA 1991		SEAM TYPE	SUIT WEIGHT (APPROX.) LBS.	COST (APPROX.) DOLLARS
	A	B	LIMITED	REUSABLE	YES	NO			
Chem Fab									
Challenge 5000		X		X		X	heat sealed	7 lbs	1,200.00
Challenge 5200	X			X		X	heat sealed/ taped	N/A	3,000.00
Challenge 6000	X			X	X		heat sealed/ taped	10 lbs	3,000.00
Chemron Max GT	X		X			X	double tape	6 lbs	412.00
Max		X	X			X	double tape		350.00
Dura Fab									
Hazard Guard	X			X		X	heat sealed	7 lbs	3,500.00
Fyrepel/Lakeland									
Forcefield	X			X	X[1]		stitched/heat sealed	6 lbs	3,400.00
Interceptor	X		X		X[1]		one side strapped	4 lbs	380.00
ILC Dover									
Chemturion	X			X		X	heat sealed	6 lbs	1,000.00
Lifeguard									
Responder	X	X	X		X[1]		serge/single or double tape	7 lbs	400.00
Tefguard	X		X			X	double tape	12 lbs	4,000.00
Butyl	X	X		X		X	single tape	15 lbs	3,500.00

1 - requires an aluminized flashover cover to meet this requirement

TABLE I (Cont'd)

NAME	CHEMICAL PROTECTIVE LEVEL		INTENDED USE		MEETS NFPA 1991		SEAM TYPE	SUIT WEIGHT (APPROX.) LBS.	COST (APPROX.) DOLLARS
	A	B	LIMITED	REUSABLE	YES	NO			
MSA First Team	X	X	X		X		double taped	5 lbs	835.00
Standard Safety CPE	X			X		X	sewn & heat sealed	N/A	2,500.00
Trelleborg									
HPS	X			X	X		double viton	N/A	4,400.00
Butyl	X	X		X		X	double butyl	N/A	2,461.00
Super Butyl/ Viton	X	X		X		X	double viton	N/A	3,985.00
Wheeler									
Butyl	X			X		X	strapped & cemented	12 lbs	900.00
Teflon/Nomex	X			X		X	Kevlar thread w/PTFE tape	12 lbs	4,200.00

N/A - information not available from the manufacturer

TABLE II

Permeation Test Results

(ASTM 739 - Breakthrough Time in Minutes)

NAME	ACETONE	CARBON DISULFIDE	DIETHYL AMINE	ETHYL ACETATE	HEXANE	METHANOL
Chem Fab						
Challenge 5000	74	12	480	114	480	480
Challenge 5200	>300	143	>300	>300	>300	>300
Challenge 6000	480	480	480	480	480	480
Chemron Max GT	480	480	480	480	480	N/A
Max	480	480	480	480	480	N/A
Dura Fab						
Hazard Guard	74	12	480	114	480	480
Fyrepel/Lakeland						
Forcefield	480	480	480	480	480	480
Interceptor						
ILC Dover						
Chemturion	C	X	B	B	A	A
Lifeguard						
Responder	480	480	480	480	480	480
Tefguard	480	480	480	480	480	480
Butyl	125	2	3	28	4	303
MSA First Team	480	480	480	480	480	480
Standard Safety						
CPE	35	12	22	30	239	N/A

TABLE II (Cont'd)

NAME	ACETONE	CARBON DISULFIDE	DIETHYL AMINE	ETHYL ACETATE	HEXANE	METHANOL
Trelleborg						
HPS	480	480	480	480	480	480
Butyl	<480	<60	<120	<480	<120	<480
Super Butyl/ Viton	<240	<480	<240	<240	<480	<480
Wheeler						
Butyl	182	1	8	59	1	480
Teflon/Nomex	480	480	480	480	480	480

N/A - information not available from the manufacturer

1 - A - RECOMMENDED
B - MINOR TO MODERATE EFFECT
C - CONDITIONAL
X - NOT RECOMMENDED

TABLE II (Cont'd)

Permeation Test Results

NAME	SODIUM HYDROXIDE	TETRA HYDRO-FURAN	NITRO BENZENE	SULFURIC ACID	TOLUENE
Chem Fab					
Challenge 5000	480	480	480	480	480
Challenge 5200	>300	>300	>300	>300	>300
Challenge 6000	480	480	480	480	480
Chemron Max GT	480	N/A	480	480	480
Max	480	N/A	480	480	480
Dura Fab					
Hazard Guard	480	480	480	480	291
Fyrepel/Lakeland					
Forcefield Interceptor	480	480	480	480	480
ILC Dover					
Chemturion	A	C	C	B	C
Lifeguard					
Responder	480	480	480	480	N/A
Tefguard	480	480	480	480	N/A
Butyl	480	9	480	452	N/A
MSA First Team	480	480	480	480	480
Standard Safety					
CPE	N/A	16	140	N/A	28

TABLE II (Cont'd)

NAME	SODIUM HYDROXIDE	TETRA HYDRO-FURAN	NITRO BENZENE	SULFURIC ACID	TOLUENE
Trelleborg					
HPS	480	480	480	480	480
Butyl	480	<240	<480	<240	<120
Super Butyl/ Viton	<480	<240	<480	<480	<480
Wheeler					
Butyl	480	11	300	480	12
Teflon/Nomex	480	480	480	480	480

N/A - information not available from the manufacturer

1 - A - RECOMMENDED
B - MINOR TO MODERATE EFFECT
C - CONDITIONAL
X - NOT RECOMMENDED

MATERIAL TEST METHODOLOGY

Following a survey of all manufacturers, materials were selected for NCTRF laboratory evaluation. Those selected for the preliminary evaluation were in the Level A category, and possessed a combination of the best chemical resistance and durability, coupled with the manufacturer's willingness to supply test material. The materials selected are listed in Table III.

Materials were subjected to a standard battery of physical tests in NCTRF's laboratory to determine durability and flame retardancy. Federal Standard 191 test methods were used for all testing, except for determination of tear strength. The tear strength test method employed was in accordance with ASTM. Test methods are listed in Table IV.

These methods are used only as a preliminary screening process for material evaluation, but once materials are selected on the basis of this information, they should be subjected to closer scrutiny. A test that best simulates actual user conditions, such as a test chamber for judging suit performance to flashovers, is being addressed by Texas Research Institute and Life-Guard.

DISCUSSION OF TEST RESULTS

Results of these physical tests are listed in TABLE V. The materials varied in weight from 8.6 - 23.2 ounces per square yard, with the polytetraflourcethylene coated nonwovens group being the lightest in weight, and also exhibiting the lowest break strength. The "Acid Master CPE" exhibited resistance to tearing that was somewhat better than the other materials tested. The CHEMFAB "Challenge 6000" material was the thinnest that was tested, but all others were essentially alike.

The flame retardant test proved the CHEMFAB "5000" and "6000", LifeGuard "TefGuard" and the DuraFab "Hazardguard" to be clearly superior to the remaining materials. The stiffness evaluation showed that the Trelleborg "Super" suit was the most flexible, and that the "Challenge 6000" was the stiffest. The balance of the materials comprised two groups within the category.

TABLE III

Materials Selected for Laboratory Evaluation

Manufacturer	Product Name	Structure
CHEMFAB	"Challenge 5000"	PTFE* coated/"Nomex" nonwoven
CHEMFAB	"Challenge 6000"	supported fluoropolymer composite
DuraFab	"Hazardguard"	PTFE* coated/"Nomex" nonwoven
Life-Guard	"Responder"	multilayer composite (proprietary)
Life-Guard	"TefGuard"	PTFE* coated/"Nomex" nonwoven
Standard Safety	"Acidmaster CPE"	chlorinated polyethylene
Trelleborg	"HPS"	multilayer composite (proprietary)
Trelleborg	"Super"	"Viton"/Butyl coated polyamide

* Polytetraflouroethylene

Materials were subjected to a standard battery of physical

TABLE IV

Laboratory Evaluation Test Methods

Federal Standard 191A Test Methods

5903.1	Flame Resistance of Cloth; Vertical
5202	Stiffness of Cloth, Directional; Cantilever Bending Method
5102	Strength and Elongation, Breaking of Woven Cloth; Cut Strip Method
5872	Temperature, High; Effect on Cloth Blocking
5874	Temperature, Low; Effect on Coated Cloth
5030	Thickness of Textile Materials; Determination of

American Society for Testing and Materials

D1424	Tear Resistance of Woven Fabrics by Falling Pendulum (Elmendorf) Apparatus

TABLE V

Physical Characteristics of Selected Materials

	WT (oz/yd^2)	BREAK WARP (lbs.)	BREAK FILL (lbs.)	TEAR WARP (lbs.)	TEAR FILL (lbs.)	THICKNESS (inches)	FLAME RESIST. WARP A/F (sec)	WARP A/G (sec)	WARP CL (in)	FILL A/F (sec)	FILL A/G (sec)	FILL CL** (in)
Challenge												
A. 6000	17.6	239	224	3.7	3.8	.014	0	2.6	.5	0	2.2	.6
B. 5000	10.2	52	30.7	10.7	3.7	.018	0	6.0	2.0	0	5.4	1.4
Life Guard												
A. Responder	8.6	40.7	29.3	3.4	2.9	.019	60^+	60^+	Bel	60^+	60^+	Bel
B. TefGuard	14.2	35	21.3	*	3.7	.026	0	10.1	1.5	0	11.2	1.2
Trelleborg												
A. Super	15.6	136	123	4.2	3.9	.018	60^+	0	Bel	60^+	0	Bel
B. HPS	17.6	154	161	5.3	4.3	.022	60^+	20	Bel	60^+	3.0	Bel
Std Safety Acid Master CPE	23.2	92	98	9.7	6.6	.024	72	57	Bel	74	73	Bel
Dura Fab Hazard Guard	10.0	45	30	8.8	3.7	.020	0	5.4	1.8	0	4.7	1.5

* Tears occurred perpendicular to the specimen slit, therefore results were invalid.
** A/F - afterflame; A/G - afterglow; CL - char length
X Insufficient fabric available to perform test.

NOTE:
Thickness .375" dia. presser foot with a total load of 3.4 ± 0.1 psi

Stiffness bending moment weight .155 Challenge 6000
.080 Challenge 5000, Responder, TefGuard
.045 Hazard Guard, HPS
.025 Acid Master CPE, Super

TABLE V (Cont'd)

	RESIST. HIGH TEMP Yes/No (180°F) (30 min)	RESIST. LOW TEMP Yes/No (20°F) (30 min)	STIFFNESS WARP	STIFFNESS FILL
			(in/lbs)	(in/lbs)
Challenge				
A. 6000	N	N	.097	.058
B. 5000	N	N	.024	.019
Life Guard				
A. Responder	N	N	.057	.052
B. TefGuard	N	N	.049	.045
Trelleborg				
A. Super	N	N	.003	.004
B. HPS	N	N	.022	.016
Std Safety Acid Master CPE	X	X	.012	.014
Dura Fab Hazard Guard	N	N	.021	.019

CONCLUSIONS

Based on discussions with the Naval Safety Center, it is concluded that a need for a Level A hazardous chemical protective ensemble does not exist for the handling of chemical spills, and that the current Spill Kit coverall is adequate. Although this coverall may suffice for the types and quantities of hazardous chemical spills that are typically encountered, the threat of fire and/or explosion associated with these chemicals needs to be addressed.

Surveys conducted with environmental coordinators and fire marshalls has revealed that a need exists for a hazardous chemical protective suit for use in firefighting applications. A suit of this kind would be invaluable for use as a firefighter's entry suit where hazardous chemicals are stored, considering that the current approach to combating fires of this type is to station the firefighter away from the fire so as not to come into contact with the chemicals.

The development of a suit of this kind would have to meet all of the criteria for NFPA 1971 "Protective Clothing for Structural Fire Fighting" and be developed around requirements such as anticipated flame temperature, exposure time to the heat source and the threat of explosion. Since NFPA 1971 is the governing document for all fire fighters, any protective equipment should conform to that document in order to improve the level of acceptability amongst fire fighters. Design considerations in developing this suit would include areas such as material weight, durability, seam construction, chemical permeation resistance, heat stress, visibility, gas-tight closures, communication devices, self contained breathing apparatus, and glove design.

This type of suit is not available in either the military or commercial world market, and would require an extensive research and development effort. The number of manufacturers that are capable of participating in this program are limited, due to the sophisticated nature of the material requirements. Based upon the market survey of producers of hazardous chemical protective garments, chemical permeation data and preliminary physical testing, three manufacturers have emerged as suitable for this program. They are Life-Guard, Trelleborg and CHEMFAB.

RECOMMENDATION

In support of the need for a hazardous chemical protective suit for use in firefighting applications, materials that possess flame retardant and chemical resistant characteristics capable of conforming to NFPA 1971 and NFPA 1991 should be further evaluated. These are the two driving criteria for an ensemble of this type, and must be achieved before any additional testing is performed.